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Indian Standard

DETERMINATION OF FERRITE CONTENT IN AUSTENITIC STAINLESS STEEL CASTINGS

ICS 77.140.80

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

February 2009 **Price Group 5**

Indian Standard

DETERMINATION OF FERRITE CONTENT IN AUSTENITIC STAINLESS STEEL CASTINGS

1 Scope

Procedures are covered for estimating ferrite content in certain grades of austenitic iron-chromium-nickel alloy castings that have compositions balanced to create the formation of ferrite as a second phase in amounts controlled within specified limits. Methods are described for estimating ferrite content by chemical, magnetic and metallographic means.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 4990:—[1], *Steel castings — General technical delivery requirements*

ISO 9042:1988, *Steels — Manual point counting method for statistically estimating the volume fraction of a constituent with a point grid*

ASTM A799, *Standard Practice for Steel Castings, Stainless, Instrument Calibration, for Estimating Ferrite Content*

BNIF 345, *Évaluation de la teneur en ferrite dans les aciers inoxydables moulés austénitiques*

3 Terms and definitions

For the purposes of this International Standard, the following terms and definitions apply.

3.1
ferrite
ferromagnetic, body-centered cubic microstructural constituent of variable chemical composition in iron-chromium-nickel alloys

NOTE Ferrite includes both delta and alpha species.

3.2
ferrite content
proportion of total volume of an iron-chromium-nickel alloy present as the ferrite phase

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[1] To be published. (Revision of ISO 4990:1986)

3.3
ferrite percentage
ferrite content expressed as a volume percent

4 Significance effects of ferrite content

The tensile and impact properties, the weldability, and the corrosion resistance of iron-chromium-nickel alloy castings may be influenced beneficially or detrimentally by the ratio of the amount of ferrite to the amount of austenite in the microstructure. The ferrite content may be limited by purchase order requirements or by the design construction codes governing the equipment in which castings will be used. The quantity of ferrite in the structure is fundamentally a function of the chemical composition of the alloy and its thermal history. Because of segregation, the chemical composition and, therefore, the ferrite content, may differ from point to point on a casting. Determination of the ferrite content by any of the procedures described in clause 5 is subject to varying degrees of imprecision which shall be recognized in setting realistic limits on the range of ferrite content specified. Sources of error are described in 5.1 to 5.3.

5 Methods of determination of ferrite content

5.1 Chemical composition method

Deviations from the actual quantity of each element present in an alloy because of chemical analysis variance, although possibly minor in each case, can result in substantial difference in the ratio of total ferrite-promoting to total austenite-promoting elements Therefore the precision of the ferrite content estimated from chemical composition depends on the accuracy of the chemical analysis procedure.

The estimation of ferrite percent by means of the chemical composition offers the most useful and most common method of ferrite control during melting of the metal

5.2 Magnetic response method

Phases other than ferrite and austenite may be formed at certain temperatures and persist at room temperature. Contamination from other ferromagnetic materials may also occur. These may so alter the magnetic response of the alloy that the indicated ferrite content is quite different from that of the same chemical composition that has undergone different thermal treatment. Also, because the magnets or probes of the various measuring instruments are small, different degrees of surface roughness or surface curvature will vary the magnetic linkage with the material being measured.

5.3 Metallographic examination

Metallographic point count estimates of ferrite percentage may vary with the etching technique used for the identification of the ferrite phase and with the number of grid points chosen for examination, see A2.

For most accurate local estimate of ferrite percent, a quantitative metallographic method shall be used.

6 Ordering information

Orders for material to this practice shall include the following as required.

a) Applicable ISO product specification or other document covering product requirements.

b) Alloy grade.

c) Required ferrite range, in volume percent, of the casting after final heat treatment.

d) Supplementary requirements, if any, desired.

e) The method to be used for the determination of the ferrite content and the location of measurements; whether on test blocks or on the castings shall be agreed between the customer and supplier.

f) If measurements are to be carried out on the castings, the location of the measurements shall be agreed between the purchaser and the supplier. In the absence of specification by the purchaser, the location may be chosen by the supplier.

7 General caution

7.1 In specifying ferrite content as required in 6 c) the purchaser shall not set limits that are in conflict with material specification requirements.

7.2 When setting ferrite content limits the purchaser shall ensure that the limits are compatible with the measurement method being used.

8 Estimation of ferrite

8.1 The ferrite content of the base metal of the casting can be estimated from the chemical composition in accordance with the Schoefer diagram (Figure B.1). For further information see annex B.

If agreed at the time of ordering the estimation can be carried out using an equivalent diagram as described in BNIF 345[2] which allows ferrite evaluation (from 0 % to 30 %) in austenitic steel castings.

8.1.1 The chemical analysis of the heat from which the castings are poured shall include the following elements whether or not required by the chemical requirements of the product specification: carbon, manganese, silicon, chromium, nickel, molybdenum, niobium and nitrogen.

8.1.2 The ferrite content of the casting shall be estimated from the central line of the diagram at the composition ratio of "chromium equivalent" (Cr_e) to "nickel equivalent" (Ni_e) determined from the following formula:

$$\frac{Cr_e}{Ni_e} = \frac{\left[\mathrm{Cr}\,(\%) + 1{,}5\,\mathrm{Si}\,(\%) + 1{,}4\,\mathrm{Mo}\,(\%) + \mathrm{Nb}\,(\%) - 4{,}99\right]}{\left[\mathrm{Ni}\,(\%) + 30\mathrm{C}\,(\%) + 0{,}5\,\mathrm{Mn}\,(\%) + 26\,(\mathrm{N}\,\% - 0{,}02\,\%) + 2{,}77\right]}$$

8.1.3 When a product analysis is made by the purchaser, it shall include the elements listed in 8.1.1. If a comparison is made of ferrite estimated from a product analysis performed by the purchaser, with that estimated from the heat analysis (see 8.1.1), reference shall be made to check analyses in ISO 4990.

8.2 Estimation of ferrite content in heat or product may be made by the magnetic response (see A.1) or metallographic (see A.2) methods on test blocks or castings respectively, if agreed by purchaser and supplier.

9 Acceptance standards

Conformance with the required ferrite range specified in 6 c) as indicated by the estimation procedure of 8.1 shall be the basis for acceptance of material supplied under this practice unless other methods of estimation are ordered as supplementary requirements, in which case the supplementary requirement shall be the basis of acceptance.

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2) Published by Editions Techniques des Industries de la Fonderie, 44 avenue de la Division Leclerc, 92310 Sèvres, France.

10 Certification

10.1 The manufacturer's certification shall be furnished to the purchaser stating that the material was sampled and tested in accordance with the specification (including year date) and was found to meet the requirements

10.2 The inspection document shall contain the results of the actual chemical analyses required by 8 1.1. and the indicated ferrite content range required. The estimates of ferrite content calculated in accordance with 8.1.2, and/or from magnetic measurements (A.1) and/or from point counts (A.2), if ordered by the purchaser, shall also be reported.

10.3 The inspection document shall be signed by an authorized agent of the manufacturer.

Annex A
(normative)

Determination of ferrite content by magnetic or metallographic means

A.1 Estimation of ferrite content by measurement of magnetic response

A.1.1 General

The ferrite content of the heat from which the castings are poured shall be estimated from measurements made by primary or secondary instruments, which have been properly calibrated for ferrite in castings. See ASTM A799 or BNIF 345. All measurements shall be made on material after the solution heat treatment required by the applicable product specification or, if any subsequent solution heat treatment is employed, then after the final solution heat treatment.

A.1.1.1 Measurements shall be made on the unstrained ends of tension test specimens from the same heat as the castings represented. Measurements may be made either before or after performance of the tension test If a tension test is not required by the applicable product specification, measurements may be made on a specimen cut from a test block as described in ISO 4990

A.1.1.2 Alternatively when specified, measurements shall be made on the base metal of the castings, or a specified sample of castings (not on weld deposits), in locations designated on the design drawing or as otherwise agreed in writing between the purchaser and the manufacturer.

A.1.2 Surface condition

A.1.2.1 The instrument magnet or probe and the surface to be measured shall be dry and cleaned prior to testing in order to remove any scale, grease, lint or dirt that could affect the accuracy of the measurement.

A.1.2.2 Measurements shall be made more than 5 mm from the edge of a surface. When measurements are made on a curved surface the radius of curvature shall be greater than 10 mm.

A.1.3 Acceptance criteria

A.1.3.1 The average of the ferrite contents estimated from measurements in each designated location shall be within the limits stated in the order, and not more than 20 % of the individual measurements shall indicate ferrite contents less than or in excess of these limits.

A.1.3.2 Should the requirements of A1.3.1 not be met, an estimation of ferrite content may be made by the metallographic method described in A2 and shall take precedence over the magnetic method.

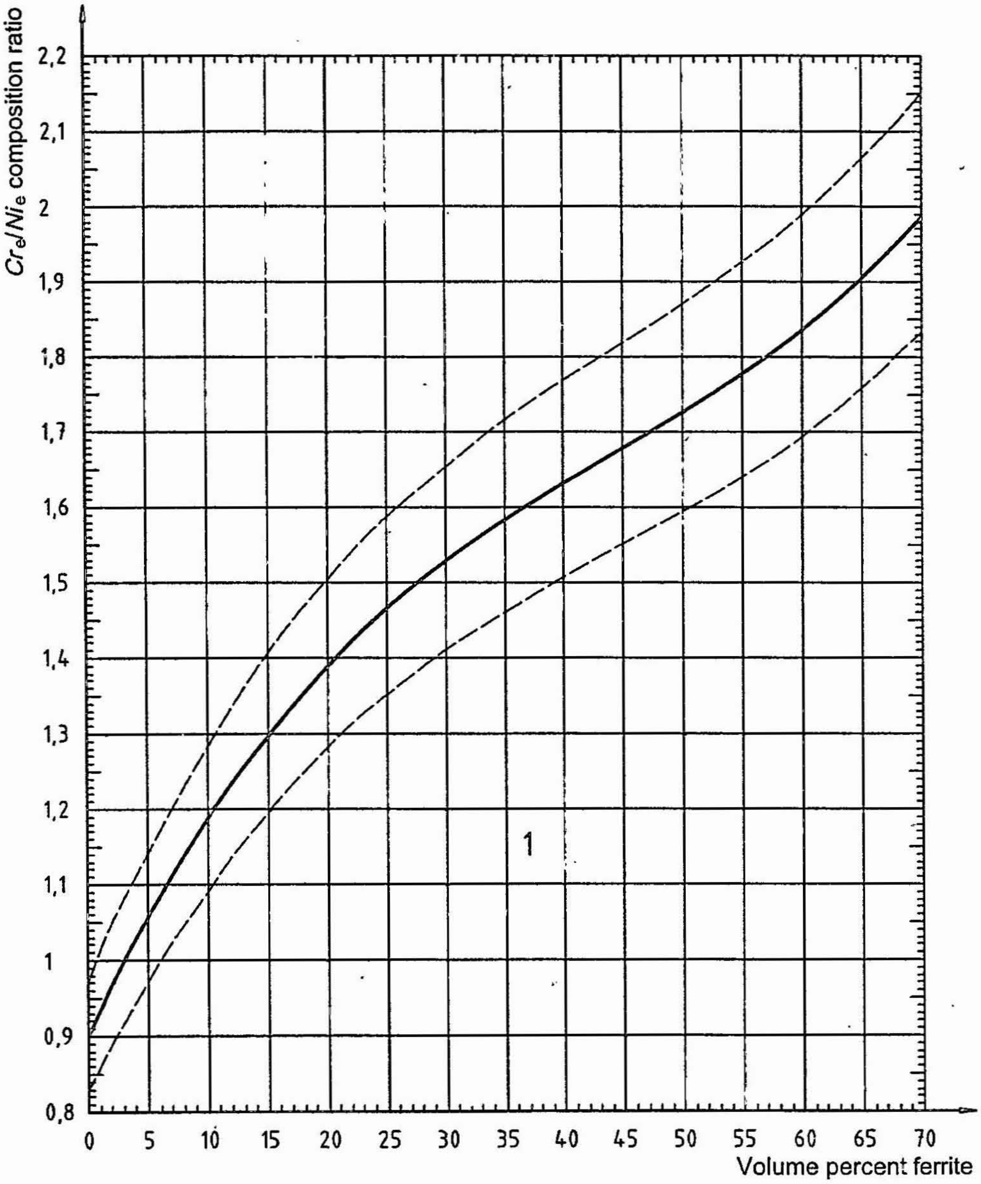
A.2 Estimation of ferrite content by metallographic examination

A.2.1 The locations of specimens to be examined shall be agreed between the purchaser and supplier.

A.2.2 Unless otherwise agreed the volume fraction of ferrite shall be estimated from the specimens by using the point count method described in ISO 9042.

Annex B
(informative)

Notes to Schoefer diagram



$$\frac{Cr_e}{Ni_e} = \frac{\left[\mathrm{Cr}\,(\%) + 1{,}5\,\mathrm{Si}\,(\%) + 1{,}4\,\mathrm{Mo}\,(\%) + \mathrm{Nb}\,(\%) - 4{,}99\right]}{\left[\mathrm{Ni}\,(\%) + 30\mathrm{C}\,(\%) + 0{,}5\,\mathrm{Mn}\,(\%) + 26\,(\mathrm{N} - 0{,}02\,\%) + 2{,}77\right]}$$

Figure B.1 — Schoefer diagram for estimating the average ferrite content in austenitic iron-chromium-nickel alloy castings

a) Figure B.1 is applicable to alloys containing elements in the following ranges:

Element	Weight %
Carbon (C)	0,20 max
Manganese (Mn)	2,00 max
Silicon (Si)	2,00 max
Chromium (Cr)	17,0 to 28,0
Nickel (Ni)	4,0 to 13,0
Molybdenum (Mo)	4,00 max
Niobium (Nb)	1,00 max
Nitrogen (N)	0,20 max

b) The Cr_e/Ni_e composition ratio necessary to produce castings within a specified ferrite content range may be read from the diagram at the intersection of the central line with the desired ferrite percentage, or may be obtained from Table B.1; e.g., for a ferrite content of 12 % the composition ratio should be 1,234.

c) The estimated average ferrite content of castings may be read from the diagram at the intersection of the central line with the composition ratio calculated from the chemical composition of the heat from which they were poured. Because of errors in chemical analyses, the calculated ratio may differ from the actual composition ratio and as a result, the ferrite content may be higher or lower than indicated by the central line. The possible extent of this difference is shown by the broken lines

If the composition ratio is 1,234, the indicated ferrite content is 12 % with a probable range from 8 % to 17 %. Similar information is available in Table B.2

If additional estimates of ferrite content are made by magnetic or metallographic methods, they can be expected to differ from the diagram value

d) The ferrite content ranges are related to the upper and lower bounds of the composition ratio that are determined from the ratios 1,04 Cr_e/0,96 Ni_e and 0,96 Cr_e/1,04 Ni_e. These correspond approximately to ± 1 sigma deviations in all the ferrite-promoting elements and + 1 sigma deviations in all the austenite-promoting elements

e) Values of composition ratio (CR) for a given ferrite content (F), or vice versa, may be determined mathematically from the equation of the central line:

$$CR = 0{,}9 + 3{,}888\,3 \times 10^{-2}\,F - 5{,}581\,75 \times 10^{-4}\,F^2 + 4{,}228\,61 \times 10^{-6}\,F^3$$

$$F = -\,68{,}768\,0 + 157{,}909\,4\,(CR) - 133{,}171\,5\,(CR)^2 + 47{,}184\,9\,(CR)^3$$

Table B.1 — Composition ratio (CR) required for a desired ferrite content

Volume % ferrite	0	1	2	3	4	5	6	7	8	9
0	0,900	0,933	0,966	0,997	1,027	1,056	1,084	1,111	1,138	1,163
10	1,187	1,211	1,234	1,256	1,277	1,297	1,317	1,336	1,354	1,371
20	1,388	1,405	1,420	1,436	1,450	1,464	1,478	1,491	1,504	1,516
30	1,528	1,540	1,551	1,562	1,573	1,584	1,594	1,604	1,614	1,623
40	1,633	1,643	1,652	1,661	1,671	1,680	1,689	1,699	1,708	1,718
50	1,728	1,737	1,747	1,758	1,768	1,779	1,790	1,801	1,813	1,825
60	1,837	1,850	1,863	1,877	1,891	1,906	1,921	1,937	1,953	1,970
70	1,988									

EXAMPLE For a ferrite content of 12 % the CR (1,234) is located at the intersection of row 10 and column 2.

Table B.2 — Volume percent ferrite indicated by composition ratio (*CR*)

Composition ratio[a]		0,00	0,01	0,02	0,03	0,04	0,05	0,06	0,07	0,08	0,09
	U	0,00	0,00	0,00	0,00	0,30	0,62	0,95	1,28	1,62	1,95
0,80		0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	L	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	U	2,30	2,65	3,00	3,35	3,71	4,08	4,45	4,82	5,20	5,56
0,90		0,00	0,30	0,60	0,90	1,20	1,51	1,82	2,14	2,46	2,70
	L	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,14	0,41
	U	5,97	6,36	6,76	7,17	7,58	8,00	8,42	8,85	9,29	9,73
1,00		3,11	3,44	3,77	4,11	4,45	4,79	5,14	5,49	5,85	6,21
	L	0,69	0,97	1,25	1,54	1,83	2,12	2,41	2,71	2,96	3,21
	U	10,18	10,64	11,11	11,58	12,06	12,55	13,05	13,56	14,08	14,61
1,10		6,58	6,95	7,33	7,71	8,10	8,49	8,89	9,29	9,70	10,11
	L	3,61	3,92	4,24	4,55	4,87	5,19	5,52	5,85	6,18	6,52
	U	15,15	15,70	16,26	16,84	17,42	18,02	18,63	19,26	19,90	20,56
1,20		10,53	10,96	11,40	11,84	12,29	12,75	13,21	13,68	14,16	14,65
	L	6,86	7,21	7,56	7,92	8,28	8,64	9,01	9,38	9,76	10,15
	U	21,23	21,92	22,63	23,35	24,10	24,86	25,65	26,46	27,29	28,14
1,30		15,15	15,66	16,17	16,70	17,24	17,79	17,79	18,92	19,50	20,10
	L	10,54	10,93	11,33	11,74	12,15	12,57	12,57	13,43	13,87	14,31
	U	29,02	29,92	30,85	31,80	32,78	33,78	34,81	35,86	36,94	38,04
1,40		20,71	21,33	21,97	22,63	23,30	23,98	24,68	25,40	26,14	26,90
	L	14,77	15,23	15,70	16,18	16,66	17,16	17,66	18,18	18,70	19,23
	U	39,16	40,29	41,43	42,59	43,75	44,91	46,07	47,22	48,36	49,48
1,50		27,68	28,55	29,29	30,13	30,99	31,87	32,78	33,70	34,65	35,62
	L	19,78	20,33	20,90	21,48	22,07	22,68	23,30	23,93	24,58	25,24
	U	50,59	51,67	52,74	53,78	54,79	55,78	56,75	57,68	58,60	59,49
1,60		36,61	37,61	38,64	39,68	40,73	41,79	42,86	43,96	45,00	46,07
	L	25,91	26,61	27,32	28,04	28,79	29,55	30,33	31,13	31,94	32,78
	U	60,35	61,19	62,01	62,80	63,58	64,33	65,06	65,78	66,28	67,15
1,70		47,13	48,18	49,22	50,25	51,26	52,25	53,22	54,17	55,10	56,01
	L	33,63	34,50	35,39	36,30	37,23	38,16	39,12	40,08	41,05	42,04
	U	67,82	68,47	69,10	69,72	70,32	> 70				
1,80		56,89	57,76	58,60	59,42	60,22	61,00	61,76	62,50	63,22	63,93
	L	43,02	44,01	45,00	45,99	46,97	47,94	48,91	49,86	50,80	51,72
	U	> 70									
1,90		64,61	65,28	65,94	66,58	67,21	67,82	68,42	69,00	69,58	70,14
	L	52,63	53,52	54,39	55,24	56,08	56,89	57,69	58,47	59,23	59,97
	U	> 70									
2,00		> 70									
	L	60,70	61,41	62,10	62,78	63,44	64,09	64,72	65,34	65,94	66,53
	U	> 70									
2,10		> 70									
	L	67,11	67,68	68,23	68,78	69,31	69,84	> 70			

[a] For a given composition ratio the ferrite content estimate is to be found at the intersection of the appropriate line and column. The figures immediately above and below on the lines *U* and *L* indicate the probable upper and lower bounds of the ferrite range that may be expected.

EXAMPLE For a *CR* of 1,23 the ferrite content is located at the intersection of line 1,20 and column 0,03, i.e. 11,84. The probable expected upper limit, *U*, is 16,84 and the probably expected lower limit, *L*, 7,92.

MGIPF—957 BIS/08—4.3.09—300 Books.

Metallography and Heat Treatment Sectional Committee, MTD 22

NATIONAL FOREWORD

This Indian Standard which is identical to ISO 13520 : 2002 'Determination of ferrite content in austenitic stainless steel casting' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on the recommendation of the Metallography and Heat Treatment Sectional Committee and approval of the Metallurgical Engineering Division Council.

The text of ISO Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker in the International Standard while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

The technical committee responsible for the preparation of this standard has reviewed the provisions of the following International Standards referred in this adopted standard and has decided that they are acceptable for use in conjunction with this standard:

International Standard	*Title*
ISO 4990 : 2003	Steel castings — General technical delivery requirements
ISO 9042 : 1988	Steels — Manual point counting method for statistically estimating the volume fraction of a constituent with a point grid
ASTM A 799 : 2004	Standard practice for steel castings, stainless, instrument calibration for estimating ferrite content
BNIF 345	Evaluation de la teneur en ferrite dans les aciers inoxydables moulés austénitiques

In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

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Amendments Issued Since Publication

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